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(54) Abstract Title
Communicating between aircraft and flight control centre using satellites

(57) Spaced-based communication system 30 comprising one or more satellites in low- or medium-earth orbit, provides communication between aircraft 60 and at least one flight control centre 40. The flight control centre can assign and monitor a plurality of grids covering a region of interest. Further, grid coverage and size can be selected on criteria such as volume of air-traffic or lime of day and the global aviation system 20 may use a single channel or dedicated channels for each grid. The communication from aircraft may include voice, fax and data such as aircraft ID and position and may be of known form e.g. digital switched network, L-, K-or S-band frequency channels, TDMA, FDMA and/or CDMA systems. The flight control centres 40 may be installed anywhere in the world without regard to the grid areas to be controlled and provide continuous communication. The satellites may also communicate with ground based subscribers (fig. 2).

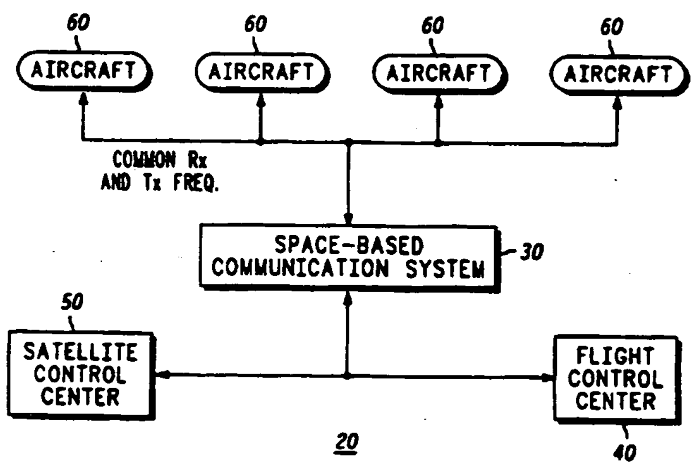

FIG. 1

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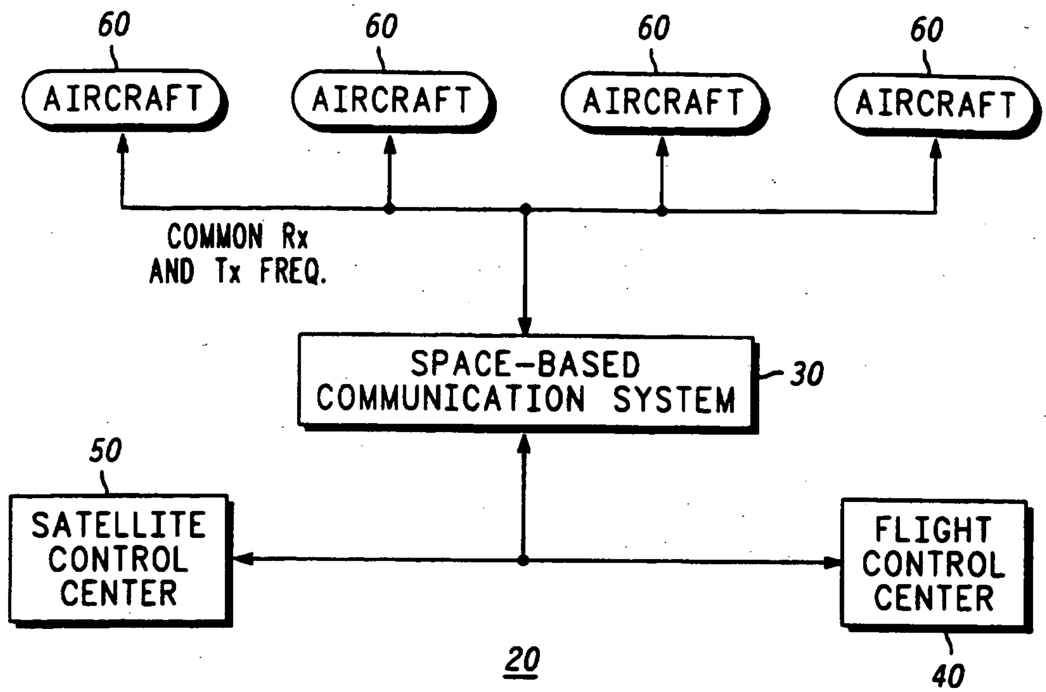
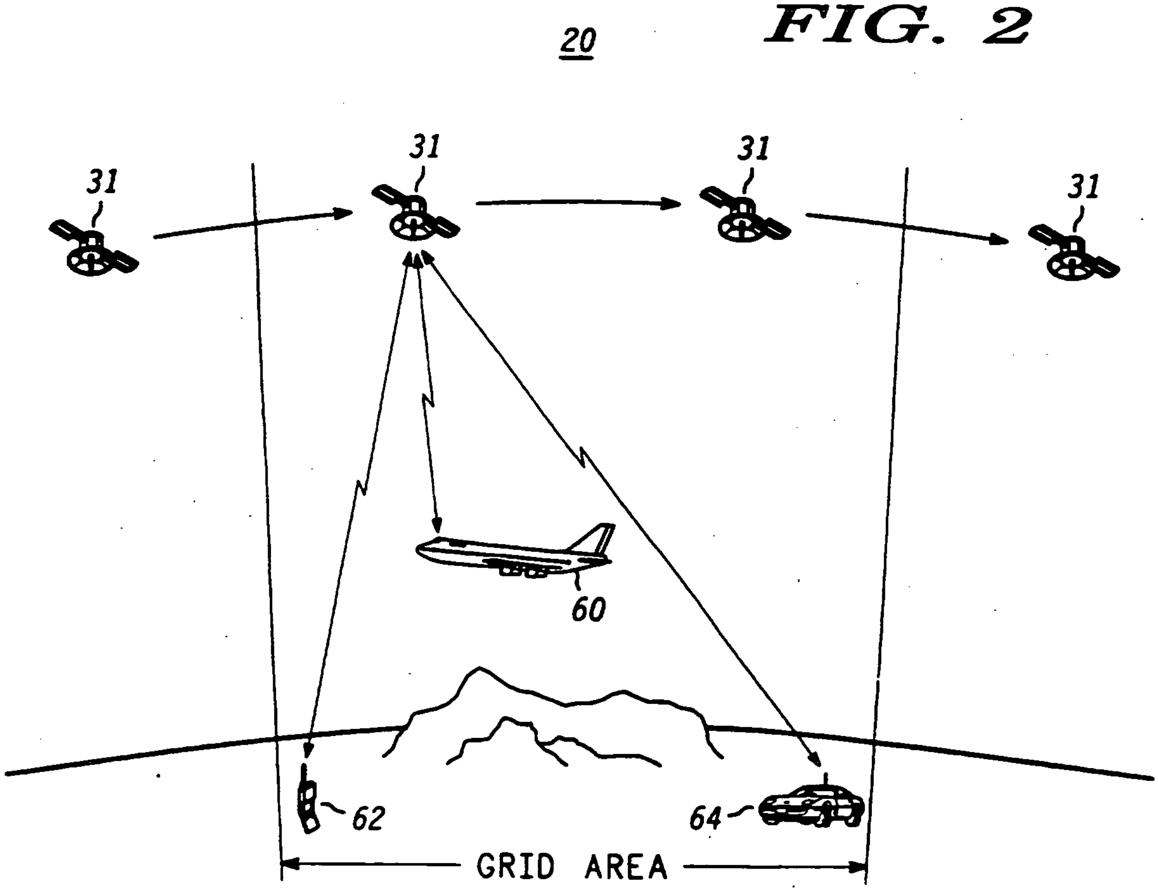


60
AIRCRAFT
60
AIRCRAFT
60
AIRCRAFT
60
AIRCRAFT
COMMON Rx
AND Tx FREQ.
SPACE-BASED
COMMUNICATION SYSTEM
30
50
SATELLITE
CONTROL
CENTER
FLIGHT
CONTROL
CENTER
40
20

FIG. 1

FIG. 2



20
31
31
31
31
60
62
64
GRID AREA

GLOBAL AVIATION COMMUNICATION SYSTEM

Technical Field

This invention relates generally to communication systems and, in particular, to global aviation communication system that provide continuous communications between aircraft and flight control centers via a space-based communication system.

Background of the Invention

The Federal Aviation Administration (FAA) and other agencies of foreign governments responsible for monitoring the commercial airspace of their countries currently use terrestrial navigation and surveillance systems to guide aircraft on a flight path across their airspace. The conventional, terrestrial navigation and surveillance systems establish continuous air-to-ground communications between aircraft and flight or control service centers.

Presently in the United States, there are approximately 28,000 terrestrial-based air-to-ground radios of which about 20,000 are very high frequency (VHF) radios. While some provide line-of-sight communications between ground controllers and aircraft, most are remote VHF radios that have telecommunications links with control and flight service centers geographically dispersed across the country.

The problems with terrestrial communication, navigation and surveillance systems is that aircraft instrument operations in uncontrolled airspace is a flight safety problem as there are no control centers to assure separation between aircraft. Thus, for safe operation aircraft have to follow a designated flight path through regions which are monitored and controlled by national flight control centers. There are many areas of the world with unmonitored regions where it is not economically or physically practical to construct a flight control center. Not only would it be costly to build and set up the ground communication, navigation and surveillance equipment, but a large field staff would be needed to control and maintain the equipment to include VHF radios and associated telecommunications networks that support them. Even those areas of the world currently with ground communication, navigation and surveillance equipment, it is very costly to operate and maintain the equipment in addition to providing telecommunications services between the equipment and flight control centers.

Accordingly, there is a significant need for aviation communication systems that can directly monitor and control aircraft in regions anywhere on the earth regardless of whether these regions are currently monitored or unmonitored with terrestrial equipment.

Brief Description of the Drawings

FIG. 1 shows a global aviation communication system according to a preferred embodiment of the present invention; and

FIG. 2 shows an example of the global aviation communication system according to a preferred embodiment of the present invention.

Description of the Preferred Embodiments

The present invention has utility in that global aviation communication systems use a space-based communication system, such as a low-earth orbit (LEO) satellite network, for example, to provide aviation communication between one or more flight control centers and aircraft. According to the present invention, a single flight control center could watch all airspace regions controlled by a particular country without using any terrestrial navigation equipment. Aviation communication can encompass two-way voice communication, two-way data communication and one-way autonomous aircraft information reports.

FIG. 1 shows a global aviation communication system according to a preferred embodiment of the present invention. As shown in FIG. 1, global aviation communication system 20 comprises space-based communication system 30, at least one flight control center 40, satellite control center 50 and any number of aircraft 60.

Space-based communication system 30 comprises one or more satellites. A "satellite" as used throughout this description means a man-made object or vehicle intended to orbit the earth. A "constellation" means a number of satellites arranged in orbits for providing specified coverage (e.g., radio communication) of a portion, portions or all of the earth. A constellation typically includes multiple rings (or planes) of satellites and may have an equal number of satellites in each plane, although this is not essential.

The present invention is applicable to space-based communication systems 30 that assign particular regions on the earth to specific cells on the earth, and preferably to systems 30 that move cells across the surface of the

earth. Satellites of space-based communication system 30 may be one of many satellites in a constellation of satellites orbiting earth. The present invention is also applicable to space-based communication systems 30 having satellites which orbit earth at any angle of inclination including polar, equatorial, inclined or other orbital patterns. The present invention is applicable to systems 30 where full coverage of the earth is not achieved (i.e., where there are "holes" in the communication coverage provided by the constellation) and to systems 30 where plural coverage of portions of the earth occur (i.e., more than one satellite is in view of a particular point on the earth's surface).

In the preferred embodiment, satellites of space-based communication system 30 are in a low-earth orbit around earth. In an alternative embodiment, satellites may be in medium-earth orbit. Low-earth orbit satellite are typically at an altitude range of 700 km to 1400 km (400 to 800 miles) altitude, while medium-earth orbit satellite at an altitude of about 10,000 km (6200 miles).

Satellites of space-based communication system 30 communicate with each other via cross-links. These cross-links form a backbone of space-based communication system 30. Thus, a call or user communication from aircraft 60, including but not limited to voice, fax and data may be routed through satellite or other satellites in the constellation to within range of substantially any other point on the surface of the earth where flight control center 40 is located. How satellites physically communicate with flight control center 40, aircraft 60 or with each other is well known to those of ordinary skill in the art. Satellites of space-based communication system 30 may also communicate with subscriber units, including but not limited to hand-held satellite telephones, facsimile machines, computers, etc.

Existing aviation radios use the VHF and UHF bands. While they have been updated, their basic technology goes back to the early 1920's. The present invention uses a digital switched system using a space-based communication network to provide point-to-point communication anywhere on the earth for future aviation communication technology. One of the objectives of the present invention is to provide two-way voice and data communication between a person on the ground and a number of aircraft within a designated area over the ground. The person on the ground could be an air traffic controller, flight service specialist, tower controller or airline operations officer. In most cases, that person is not located within the designated area.

Flight control center 40 is where a number of air traffic controllers watch a single or multiple air space regions that are referred to as grids. The grid can be a 3-dimensional assigned airspace where coverage area is determined by altitudes and GPS locations.

There may be a single flight control center 40 for the world, where all the airspace around the earth is watched. However, because each country usually wants to watch its own airspace (due to national security and other concerns), there may be a single flight control center 40 or multiple flight control centers 40 for each country.

Global aviation communication system 20 has at least one flight control center 40. There may be one or more flight control centers 40 for each country in the world. Each flight control center 40 has automatous control over the airspace region for which it is responsible and will not be given access to communication outside its region. Each flight control center 40 has a direct communication link into space-based communication system 30 for receiving transmissions from and sending transmissions to the region under its control.

Flight control center 40 may include units for displaying the locations of all aircraft in a particular region. An identifier on the display could blink and change color to indicate communication has been established between a controller at flight control center 40 and aircraft 60. Aircraft and flight plan information could also be displayed automatically on the bottom of the display. There are many ways in which flight control center 40 could be configured and the way in which aircraft and flight information could be displayed. The many configurations and visual displays are well known to those of ordinary skill in the art.

Flight control center 40 divides the airspace of the region for which it is responsible into grids or coverage area or the like. A computer could be used to divide the airspace of a country, multiple countries or the world into a number of grids. A single grid may cover a large or small area and may be selected by flight control center 40 based on a variety of criteria, including for example, a number of aircraft that are predicted to be in a particular grid during a set period of time. For example, flight control center 40 for the United States may divided the U.S. into five grids during the daytime hours and one grid for the night-time hours (since there are fewer flights during the night). For the daytime hours, there may be a separate grid that covers the east coast states, midwest states, western states, Alaska and Hawaii. For night-time, a single

grid could cover the entire airspace of the United States, including Alaska and Hawaii. Each designated grid area is uploaded to satellite control center 50.

Once the flight control center 40 divides an assigned airspace into a number of grids, flight control center 49 selects, assigns and manages one or more air traffic controllers to monitor one or more grids for a certain period of time. If the grids change, the controller assigned to that grid may change as well. The air traffic controller is responsible for establishing communication with aircraft 60 entering its grid and tracking aircraft 60 while in the grid. If aircraft 60 exits the first controller's grid, communication is passed to a second controller responsible for monitoring and tracking any aircraft entering its grid. Since the grids may overlap, aircraft 60 may be able to communicate with two different controllers while in the region where the grids overlap.

Because multiple grids and flight control centers 40 could be used in global aviation communication system 20, each flight control center 40 must communicate constantly with other flight control centers 40 that monitor and control adjacent airspace regions. Thus, aircraft 60 moving from one grid to another grid may have to be transferred to another adjacent flight control center 40.

For each of the designated grid, a single channel is dedicated in each satellite of space-based communication system 30. The single channel ensures a call between a pilot will never be dropped or interrupted. Satellite control center 50 guarantees the uninterrupted connection between flight control center 40 and aircraft 60 (via space-based communication system 30). In an alternative embodiment of the present invention, global aviation communication system 20 dedicates individual channels to each aircraft 60.

Satellite control center 50 controls and monitors the performance of the satellites in space-based communication system 30. Satellite control center 50 ensures that the satellites stay in their proper orbit. Satellite control center 50 also ensures that the communication between flight control center 30 and aircraft 60 is dedicated and never dropped.

Each of flight control center 40 and satellite control center 50 comprises a number of computers (including many processors) and many communication units. These communication units make it possible to communicate with space-based communication system 30 (or directly with the satellites of system 30).

Global aviation communication system 20 may accommodate any number of aircraft 60. Aircraft 60 comprises any commercial or military aircraft used today or in the future. Communication units aboard aircraft 60 are capable of receiving voice and/or data from satellites in space-based communication system 30. By way of example, communication units of aircraft 60 may be hand-held, mobile satellite cellular telephones adapted to transmit to and receive transmissions from satellites. Moreover, the communication units of aircraft 60 may be computers capable of sending flight data and information, messages, video signals or facsimile signals just to name a few.

How communication units of aircraft 60 physically transmit voice and/or data to and receive voice and/or data from satellites is well known to those of ordinary skill in the art. The communication units may communicate with space-based communication system 30 using a limited portion of the electromagnetic spectrum that is divided into numerous channels. The channels are preferably L-Band, K-Band, S-band frequency channels or combinations thereof, but may encompass Frequency Division Multiple Access (FDMA) and/or Time Division Multiple Access (TDMA) and/or Code Division Multiple Access (CDMA) communication or any combination thereof. Other methods may be used as known to those of ordinary skill in the art.

Global aviation communication system 20 may use a single, common channel with a transmit frequency channel and a separate receive frequency channel. Space-based communication system 30 directs aircraft 60 entering into a designated grid to select a channel for communicating with flight control facility 40. If a single channel is used, communications transmitted from flight control center 40 are received by all aircraft 60 defined in the designated grid area.

When aircraft 60 communicates with flight control center 40 through space-based communication system 30, the following method may occur. First, aircraft 60 checks a local system flag (e.g., TX_FLAG) to determine whether the transmit frequency is being used by another aircraft 60. The local system flag is updated and controlled automatically by the aircraft's communication device or manually by the pilot. If manual, each pilot monitors the communications of the other pilots and determines whether the flag should be set. The state of the flag determines whether the pilot can connect to an air traffic controller.

One of the goals is to decrease the load on space-based communication system 30 by transferring the connection gating to each aircraft 60. In the event of an aircraft emergency, an aircraft may be given a higher priority to override less critical communications.

Each time aircraft 60 transmits to flight control center 40, it may be in the form of a sub-level digital tag that precedes the audio signal. When aircraft 60 completes its transmission to flight control center 40 (i.e., user dekey), another sub-level digital tag may be sent to notify all aircraft 60 to update their transmit control flag.

Second, if the local system flag is not busy, then flight control center 40 allows a connection to be made to aircraft 60. Once this connection is established, all other aircraft 60 monitoring the controller's channel update their local system flag as busy until the pilot disconnects with the air control center 40 .

Third, if the local system flag is busy, then flight control center 40 indicates to aircraft 60 that system 20 is busy. Whenever a transmission is received by space-based communication system 30 from aircraft 60, space-based communication system 30 either establishes a connection to aircraft 60 if the controller's channel is open, or signals to aircraft 60 that the controller's channel is busy. Most pilots are trained in the use of 2-way radio communications and typically wait for a channel to open before transmitting to the air traffic controller. One of the goals of the present invention is to decrease the load on the space-based communication system and eliminate conflicts that can arise by use of a single channel by multiple users.

An alternative embodiment to the method described makes aircraft 60 when it is departing dial a terrestrial cellular telephone number by using the aircraft's telephone equipment. A dedicated telephone number would remain the same throughout the entire flight. Terrestrial cellular equipment located in the vicinity of the airport would forward the call to flight control center 40 where the call is transitioned to space-based satellite network 30 while airborne. While airborne, each designated grid area would be a "conference bridge" with all aircraft within the designated area being added to the bridge when entering the area and being taken off (and sent to the next bridge) when exiting the area. In addition to voice communication, the digital communication from each aircraft includes in the background (not heard by the pilot or ground controller) two-way data communication and one-way

aircraft position data (most likely global positioning system (GPS)). The switch may be automated over from one area to the next with software based upon each aircraft's position and designated area boundaries. All calls within such a grid area are bridged with the controller's transmissions so all parties could hear all transmissions. This allows a party to the bridge to not transmit while another party is transmitting. This will significantly reduce ground controller workload thus allowing more time and attention on maintaining safe separation between aircraft.

By using a single, common channel, global aviation communication system 20 appears tc be a full duplex communication system. When a pilot aboard aircraft 60 wishes to contact an air traffic controller at flight control center 40, the pilot may have to engage a push-to-talk (PTT) switch to engage transmission (although other commercially available pilot transmission systems known to those skilled in the art work just as well). Communication between the pilot and flight control center 40 appears as full duplex communication, and no other pilot is allowed access to the controller's channel.

Global aviation communication system 20 can also support two way data communications, including but not limited to, aircraft identification, time, location, airspeed, altitude, and flight data such as clearances, weather and notices to airmen. This information can be transferred in two different ways. First, data can be transferred before voice communications. This is transparent to the pilots and appear as real-time to the air traffic controller. An aircraft identifier can also be accessed by flight control center 40 during the call and requires little controller interaction. An aircraft's location can then be updated on the air traffic controller's visual display for immediate location of the aircraft.

Second, flight control center 40 may use a data controller to poll all current aircraft users one-by-one to update pertinent flight information and/or data on demand. This may be handled through a controller channel and the sampling rate can be predetermined. If traffic in a designated area becomes too great, then data communications can be moved onto a separate channel from voice. Flight control center 40 can contact aircraft 60 monitoring the controller channel to transfer data transparently. Aircraft 60 transmitting to flight controller center 40 updates data directly to flight control center 40 and needs no polling.

An aircraft's current position, time and trajectory information can be downloaded to the air traffic controller at flight control center 40 through space-based communication system 30. Flight control center 40 controls sampling rate and determines if it can adequately service the current system load.

In global aviation communication system 20, voice transmissions can also be encrypted to prevent intrusions from unauthorized persons. Encryption keys could be passed from flight control center 40 upon first contact within each area without any action by the pilot or the air traffic controller. There are other ways to encrypt voice which are well known to those of ordinary skill in the art that can be implemented in system 20.

FIG. 2 shows an example of the global aviation communication system according to a preferred embodiment of the present invention. Satellite 31 of space-based communication system 30 (FIG. 1) establishes communication with aircraft 60 located in a particular grid area. Satellite 31 may also establish communication with other communication units, including for example, satellite telephone unit 62 and satellite car phone 64. As shown in FIG. 2, satellites 31 replace the terrestrial navigation and surveillance equipment. However, because each satellite 31 is moving with respect to the earth's surface, service for a specific area must be passed from one satellite to another such that the primary satellite is in view of every point on the ground within the defined grid area. Additionally, the primary satellite must retune to a separate receive and transmit frequency programmed for use with the defined grid area.

As aircraft 60 travels from one designated area to the next, flight control center 40 uploads pertinent flight information to aircraft 60. Information on aircraft 60 is also passed along to the next flight controller which handles flight information for aircraft 60 once aircraft leaves the designated airspace (and grid) handled by the first flight controller 40.

It will be appreciated by those skilled in the art that the present invention provides a global aviation communication system for continuous voice and/or data communication between aircraft and a flight control center via a space-based communication system. There are many advantages to the present invention. An advantage of the present invention is that flight control centers can be installed anywhere in the world. Another advantage of the present invention is that flight control centers to be consolidated into any

location without regard to the areas to be controlled. Yet another advantage is that the present invention significantly reduces the communication workload of both pilots and air traffic controllers. A further advantage of the present invention is terrestrial surveillance systems, such as radar, is eliminated because aircraft position data is included in the background transmission. Because the present invention combines voice, data and aircraft position, significant cost savings are realized while improving operational communications especially in remote areas of the world, including areas over the oceans. Another advantage of the present invention is that communications can be directed through the space-based communication system without the need for any terrestrial ground lines or third party communication systems. An advantage also realized is increased communication reliability and elimination of the many hazards that have impeded the current, conventional system used by the FAA. Yet another advantage of this proposal is that present geosynchronous communication satellites do not provide communication coverage for aircraft over polar areas due to blockage from the earth's curvature. These communication satellites also have a time delay that slows down voice communication and have a need for aircraft tracking antennas due to extreme distance (23,000 miles) from the earth.

Accordingly, it is intended by the appended claims to cover all modifications of the invention which fall within the true spirit and scope of the invention. For example, the present invention does not depend upon a particular type of radio technology or frequency band or how it is used to support terrestrial communications.

CLAIMS

What is claimed is:

1. A system comprising:

a flight control center; and

a space-based communication system comprising a plurality of satellites capable of supporting communication between the flight control center and a plurality of aircraft.

2. A system as recited in claim 1, wherein the flight control center includes means for dividing a region into a plurality of grids.

3. A system as recited in claim 2, wherein the flight control center further includes means for assigning at least one air traffic control to monitor each of the grids.

4. A system as recited in claim 2, wherein the flight control center further includes means for assigning a dedicated channel to each of the grids.

5. A system as recited in claim 2, wherein the flight control center further includes means for assigning a plurality of dedicated channels to each of the grids, the dedicated channels being non-interfering when adjacent to each other.

6. A system as recited in claim 1, wherein the flight control center includes means for dividing a region into a plurality of grids for each of a plurality of time periods.

7. A system as recited in claim 6, wherein the flight control center further includes means for assigning at least one air traffic control to monitor each of the grids for each of the time periods.

8. A system as recited in claim 1, further comprising a plurality of flight control centers.

9. A system as recited in claim 8, wherein each of the flight control centers includes means for dividing its assigned region into a plurality of grids.

10. A system as recited in claim 9, wherein each of the flight control centers further includes means for assigning at least one air traffic control to monitor each of the grids.

The Patent Office

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Application No: GB 9723402.5	**Examiner:** Anita Keogh
Claims searched: 1-10	**Date of search:** 8 April 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): H4L (LDRRX, LDRRS)

Int Cl (Ed.6): H04B (7/185, 7/19, 7/195), G08G (5/00, 5/04)

Other: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	WO 96/16489 A1	(MOTOROLA) see particularly abstract, figure 4 and page 7, lines 20-26	1, 8
X	WO 89/04002 A2	(HUGHES) see particularly page 9, line 5 to page 10 line 39 and figure 1	1 at least
X	WO 88/01392 A2	(MITRE) see particularly page 2, lines 12-13, 25-27 and figures 1, 2 & 5	1, 8 at least
X, P	US 5627546	(CROW) see particularly column 1, lines 15-21, 47-55 and figure 6	1 at least
X	US 5381140	(KURODA et al.) see particularly abstract, column 4, lines 3-14 and figure 1	1 at least
X	US 4117267	(HABERLE et al.) see whole document, particularly column 1, lines 48-9 and fig. 1	1 at least

X Document indicating lack of novelty or inventive step	A Document indicating technological background and/or state of the art.
Y Document indicating lack of inventive step if combined with one or more other documents of same category.	P Document published on or after the declared priority date but before the filing date of this invention.
& Member of the same patent family	E Patent document published on or after, but with priority date earlier than, the filing date of this application.